Breaking and Splitting asteroids by nuclear explosions to propel and deflect their trajectories

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Abstract

Splitting by atomic bombs an asteroid in flight is the best way to deflect its trajectory. How and when it should be done is described.

We might need , in a near or late future to deviate incoming asteroid [1] as the approaching 1997XF11, at maximal deflection angle for any given input energy E, energy which may be due to energetic nuclear explosions. If the explosion shock wave will hit near the asteroid surface their blast will deposit by pure radiation pressure only a small momentum: $\Delta P_{\perp} = E/c$, leading to a negligible deviation angle on the asteroid trajectory:

$$\Delta\theta = \frac{\Delta P_{\perp}}{P} = \frac{E}{M\, V_o\, c} = 10^{-11}\left(\frac{E}{20\; MT}\right)\left(\frac{V_0}{30\; km\; s^{-1}}\right)^{-1}\left(\frac{M}{10^{16}\; g}\right)^{-1} \tag{1}$$

where M and V_0 are the asteroid mass and present velocity at characteristic values and the thermonuclear energy unity, i.e. tens of Megatons. This poor deviation angle, even if applied now, will be by many orders of magnitude too small to move the final trajectory far away from the Earth target. On the contrary the same amount of energy (nearly a thousand Hiroshima bomb energy), while splitting the body, may offer a "sufficient kinetic" kick to deflect the main asteroid body and its secondary massive fragment. The bomb must explode on the asteroid or, better, inside it and it must expel a fragment of mass m_1. The large efficiency in deviate the asteroid breaking its body derive by simple Newtonian cinematic formula below.

Let us label respectively the main asteroid mass and velocity (toward Earth) (M, V_0) and its fragment mass and velocity (in the center of mass, c.m., system) (m_1, v_1) and, finally, the main relic asteroid body and velocity (also in c.m. system) ($(M - m_1)$, v_2). Assuming an efficient conversion of the nuclear blast in kinetic energy in breaking the asteroid of the order of unity, one finds at general relativistic and non-relativistic regimes:

$$
\begin{aligned}
E &= m_1 c^2 (\gamma_1 - 1) + (M - m_1) c^2 (\gamma_2 - 1) \simeq \\
&\simeq \frac{1}{2} m_1 {v_1}^2 + \frac{1}{2} (M - m_1) \, {v_2}^2
\end{aligned} \tag{2}
$$

$$
E \simeq \frac{1}{2} \frac{M}{m_1} (M - m_1) \, {v_2}^2 \tag{3}
$$

when m_1 is smaller than E/c^2 then the relativistic equation applies and one gets the same result as in equation 1; otherwise ($(M - m_1) \gg m_1 \gg E/c^2$) the non-relativistic approximation holds and we apply momentum conservation for equation 3. Consequently the deviation angle for the main relic object (if the applied momentum is orthogonal to the primordial one) is:

$$
\begin{aligned}
\tan \Delta\theta_2 &= \frac{v_2}{V_0} = \frac{\sqrt{2 m_1 E}}{\sqrt{M \, (M - m_1)} \, V_0} \simeq \\
&\simeq 4.5 \cdot 10^{-5} \left(\frac{m_1}{10^{12} g} \right)^{\frac{1}{2}} \left(\frac{M}{10^{16} \, g} \right)^{-1} \left(\frac{V_0}{30 \, km \, s^{-1}} \right)^{-1} \left(\frac{E}{20 \, MT} \right)^{\frac{1}{2}}
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
\tan \Delta\theta_1 &= \frac{v_1}{V_0} = \frac{\sqrt{2 \, (M - m_1) \, E}}{\sqrt{M \, m_1} \, V_0} \simeq \\
&\simeq 0.3 \left(\frac{m_1}{10^{12} \, g} \right)^{-\frac{1}{2}} \left(\frac{E}{20 \, MT} \right)^{\frac{1}{2}} \left(\frac{V_0}{30 \, km \, s^{-1}} \right)^{-1}
\end{aligned} \tag{5}
$$

where $\Delta\theta_1$ and $\Delta\theta_2$ are the deflection angles of the vectors v_1 and v_2 with respect to the incoming direction of the asteroid; we assumed a fragmentation mass m_1 corresponding to a hundred meter volume, comparable to a small nuclear bomb "crater". The above deflecting angle $\Delta\theta_2$, while small, is large enough to divert the trajectory of the bolid at a reasonable impact parameter, either if acted now or even at a quarter of its present distance. Indeed for a quarter of distance of the "dangerous" 1997XF11, $D/4 \simeq -\frac{26}{4} y \cdot V_0 \simeq 2 \cdot 10^4 sec \cdot c$, a Jupiter like distance, one derives the final impact parameter distance Δb:

$$
\Delta b \ \simeq D \, \Delta \, \theta_2 \ \approx \ 40 \ R_\oplus \tag{6}
$$

i.e. a distance which is comparable with a (save) Moon distance. Let us note that $\Delta\theta_2$ is nearly five million times larger than $\Delta\theta$ in equation 1: therefore no doubt that the fragmentation process is a key propelling mechanism in deflecting asteroid trajectories. Technical problems to dig at deep (tens, hundred meter) a nuclear bomb arises.

A "cooperative" group of explosions at a "corona" of few hundred meters, may "bite" and "cut" an asteroid piece at better way; however synchronization of instruments of such distances may be problematic (even if multiple nuclear heads have been widely developed). A "land-off" of many nuclear heads and their coherent explosion may be the best solution. From equation 4 one notices that the deflection angle by fragmentation grows only by the square root of the nuclear energy. Therefore four times (E/4) energetic bombs in "coherent" explosions, may do a total deflection twice larger than an unique one of the same total energy E. Therefore in principle a sequence of mini explosions may kick gently and more efficiently the asteroid path. However an open problem is to blast in the correct way (or side) the bombs in phase with their previous vectorial momentum kicks. This problems may be within technological solution. Finally an asymmetric asteroid may offer protuberances to be easily broken by nuclear bombs.

Let us notice that as the time grows also the needed deflection angle increases as shown in equation 4, calling for a fragmentation energy which increases quadratically with time. For this reason the urgency of the present article related to the 1997 XF11 incoming which is submitted to the scientific attention. The maximal deflection reachable occurs (from equation 4) when $\Delta\theta_1 \simeq \Delta\theta_2$, i. e., when there is enough energy to split in two equal parts the asteroid. Then the splitting angle is:

$$\begin{aligned} \tan\Delta\theta_{max} &\simeq \sqrt{\frac{2\,E}{M\,{V_0}^2}} = \\ &= 4.5\cdot 10^{-3}\left(\frac{M}{10^{16}\,g}\right)^{-\frac{1}{2}}\left(\frac{V_0}{30\;km\;s^{-1}}\right)^{-1}\left(\frac{E}{20\;MT}\right)^{\frac{1}{2}} \end{aligned} \tag{7}$$

The above value is hundred million times better than the deflection angle in equation 1. Energetic bounds on the energy needed to break at half a Km^3-size asteroid are small (on the contrary the energy needed to "evaporate" a Km^3-size mountain are severe, i.e. $E \gg 20\,MT$) but the cut and split in half may be technically difficult and dangerous. It is auspicable that a half asteroid would be sent towards the Sun, which may keep "clean" in future our Solar System. There are moreover interesting consequences associated with the nuclear fragmentation of asteroids: 1) Let us remind the fragments problems of Patriots rockets during the Gulf-War. A secondary fragment while thousands of times smaller than the main asteroid is widely deflected by angle $\Delta\theta_1$ in equation 5, with no secondary danger. 2) If one speculate on the possibilities that intelligent life ever existed in the past in our solar system, and if it had to face similar problems finding analogous conclusions (nuclear bombs to kick asteroids), than we may expect: (a) some asteroids may be still radioactive or chemically polluted by past explosions. (b) their puzzling morphology may reflect their past explosive kicks. In this speculative framework we remind the recent discovery of "gruviera" like asteroids objects.

Moreover we speculate that (c) the asteroids may tell us on their surface nature. Indeed very recent observations [1] inform us on two possible distint population (neutral colour and redder colour asteroids) of Kuiper-belt asteroid objects (KBOs). These two group have not correlation between colour and any physical or orbital parameter. Such asteroidal bimodality may testimony that some asteroids have been heated and melted. May really the dark ones be relics of such nuclear explosions and deflections?

In conclusion we notice that a "slow" incoming asteroid ($v_F \leq 10 Km/sec$) may be also captured in an orbit around the Earth. If it will be co-rotating with our planet it may find a stable orbit (like our Moon), while in case of contro-rotating trajectory it may be slowly attracted (by tidal or "Riemann" forces) towards Earth; longer times may offer a proper solution to face with "Damocles knife" hanging over our children's heads. The steady presence of an very heavy orbiting massive asteroids (mini Moon of hundred Kms size) in a bound trajectory around Earth may influence and disturb life by periodic mini tidal waves. Moreover nearby encounters by visiting planets (or miniplanets) may induce severe tidal strains , by responsable of past mass extinctions observed on the Earth past [2]. The captured asteroid destruction by tidal forces may lead to the appearance of a final spinning ring around our planet at smaller scales as the Jovan or Saturnine rings. In conclusion in order to avoid a unique death-life experiment it may be worthfull to test the ability in deflecting asteroids by splitting their mass on other objects (small scales asteroids) at save trajectories and distances. Finally the world danger due to asterodis "shadows" may offer a dramatic probe for the international community to judge the fragility of life. Such dangers call for stronger cooperation in prospective of a solid peace among people able to preserve life from within or outside challenges.

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References

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[2] D.Fargion and A.Dar,"Tidal effects of passing planets and Mass Extinctions" astro-ph/9802265